Exploring the Design Space of InterActive Urban Environments
triggering physical activity through embedded technology

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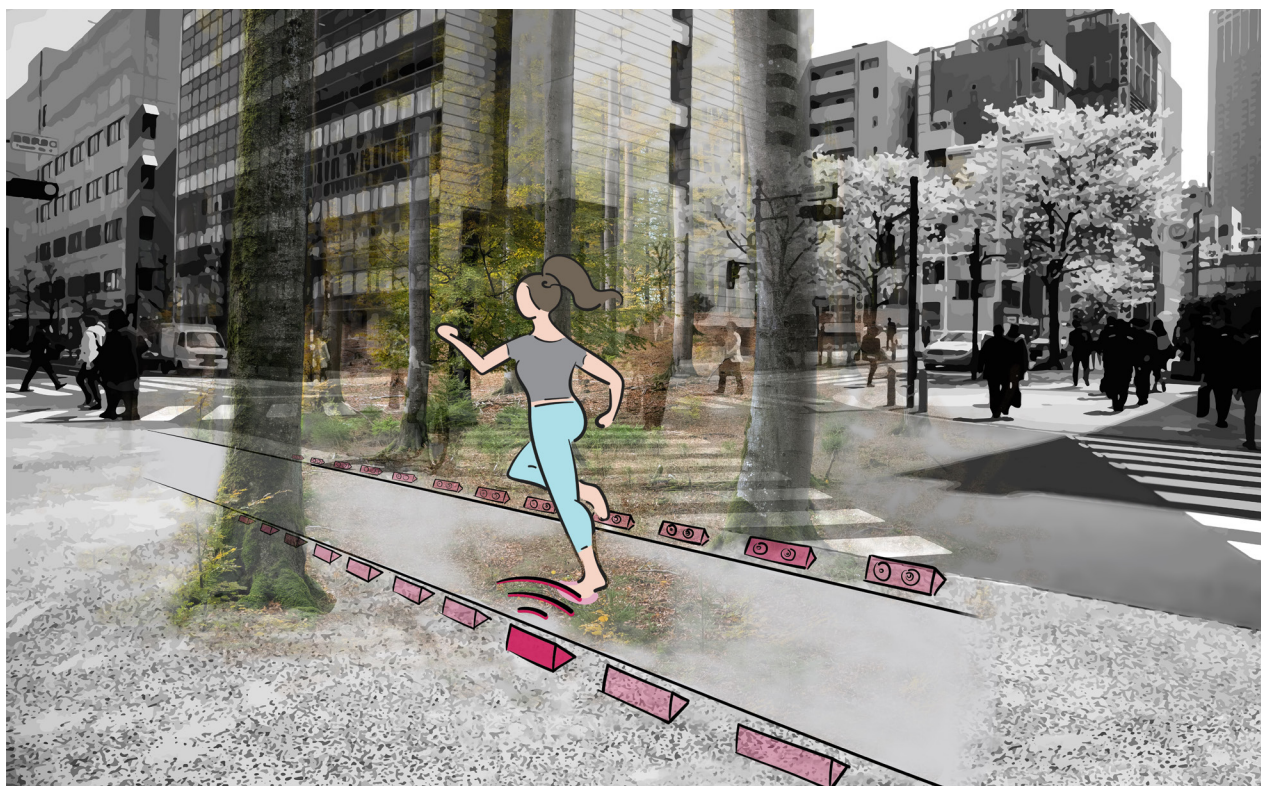Luxembourg, c.e.lallemand@tue.nl

ABSTRACT

Promoting healthy lifestyles is an essential endeavor for public health. The design of active urban environments can be an effective medium to nudge people into moving. With technology increasingly integrated into our daily lives, designers have access to more data than ever. In this pictorial, we explore the design space of interActive environments (contraction of 'interactive' and 'active'); places designed to increase the physical activity of users or passers-by through the use of interactive technology. Through sketches, a benchmark of existing concepts and an analysis of designed artefacts, we map the different intervention levels, interaction modalities, behavior change strategies and technological opportunities to design such interActive environments. With this work, we invite the community to consider how digital technology can help understand and shape human behavior in urban environments, and provide inspiration to designers and practitioners.

Authors Keywords
InterActive environment; Urban environment; Physical activity; Design space; Interactive Technology.

CSS Concepts
• Human-centered computing~Interaction design ~Interaction design process and methods

INTRODUCTION

Physical inactivity and the resulting health concerns are a key societal challenge in modern western societies [4][21][41]. Promoting healthy and active lifestyles is thus a timely topic for public policies as well as across multiple research fields. In this pictorial, we address physical inactivity specifically, which is influenced by a combination of individual, social and environmental factors [16][17]. Design of 'activating' urban environments can be an effective trigger to subconsciously nudge people into moving [34]][23]. Within the design community, we see opportunities in the field of active environment design [14][22], as well as in the ongoing shift towards Human-Environment Interaction (HEI)[37][39], where technology is increasingly integrated in the environment and is therefore omnipresent while less noticeable. These smart environments also allow for new types of feedback [37], and new levels of personalization of the environment, also an important factor in persuasive technology [3].

In this pictorial, we explore the design space of interActive environments, which we define as interactive environments that encourage physically activity behaviours, focusing on three aspects: the interaction modality, the intervention strategy and the technology used. Through our research, we investigate the potential of embedding interaction into the environment to engage a broad audience of users, including those who did not consciously decide to work out or download an activity app. Therefore, these 'accidental' encounters can broaden the impact of design interventions for physical activity, by involving a hard to reach but important target group.

A number of commercial solutions, public installations and exploratory prototypes that use technology in the outdoor environment as a trigger for physical activity have been designed, but to the best of our knowledge these efforts have yet not been drawn together or analyzed on a broader scale.

The presented design space exploration combines the results of a (1) benchmark of existing active environments, partly based on expert interviews, (2) sketching explorations with industrial design researchers and students, and (3) four use case analyses. This illustrated analysis of the design space of interActive environments is meant to inspire researchers and designers, and to pave the way for new designs and applications, optimizing the role of technology to shape meaningful experiences.

BENCHMARK

We started our design space exploration by benchmarking existing interActive environments, places purposely designed to increase the physical activity of users or passers-by through the use of interactive technology. In addition, we conducted semi-structured interviews with 11 professionals involved in the design of interActive environments. We purposely combined perspectives from different disciplines, including industrial designers (n= 4), architects and urban planners (n=3), policy makers (n=4), some of them being also design researchers. In addition to our own benchmark, we asked each of these experts to provide us with typical examples of active urban environments, ideally including an interactive/technological component. These examples were discussed during the interview to understand what characteristics made them suitable to be described as active environments, which strategies were used to trigger people to be more active, what were the gaps in the design space especially related to the use of technology and data, and the underlying challenges for future development in this area.

Out of our scope are the numerous active environments which do not make use of technology (e.g., healthy routes, bare foot paths, walking meeting routes), rely solely on mobile technology without any intervention in the physical environment, as well as installations that specifically target children (e.g., smart playground design). Smartphone apps that use the physical environment [Figure A] in the context of sports training (e.g., visualizing one's running route) or location-based exergames (e.g. Pokémon GO [29]) gained popularity in the last decade. While these make use of the physical environment (e.g., PokéStops in Pokémon GO are located on points of interest in the real world) or even augment it using Augmented Reality, they are not in the scope of interActive environments as no actual artefact nor technology is placed in the real world. Playground design increasingly make use of technological components in order to promote cognitive, social and motor skills development [13]. While these outdoor play technologies might be relevant to consider, we narrowed our scope down to design concepts not targeted at this specific children audience.

Our benchmark allows us to distinguish several categories of designs, illustrated and annotated in the following pages: public recreational sports environments, temporary high-tech sports facilities, interactive public installations and active office environments. Noteworthy, we also found an important number of student and research projects conducted at design universities within interaction design or interactive environments curriculums. These numerous prototypes, while showcasing innovative properties, however remain at a conceptual stage, and are usually not deployed nor implemented in the public space. Benchmarking existing designs is worthwhile to understand success factors, challenges or limitations, as well as identifying the gaps and future design opportunities.
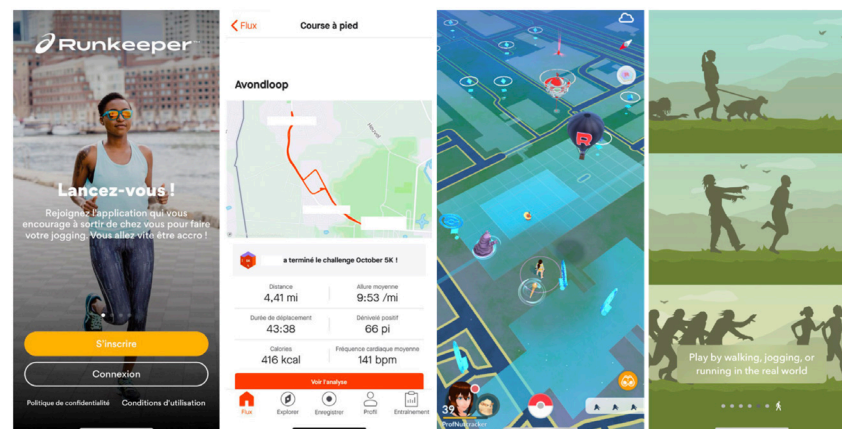

Figure A: Smartphone applications associated with physical activity and connected to the physical environment. fltr: Runkeeper [15], Strava [38], Pokémon Go [29] and Zombies, Run! [36]

BENCHMARK ON INTER-ACTIVE ENVIRONMENTS

Public recreational sport environments

Environments targeted at recreational sporters/runners are often located in public parks and green urban areas or on sports fields. These designs are usually composed of modular elements, robustly integrated in the environment in order to resist weather conditions, intensive outdoor use and sometimes vandalism. Some running track equipment designers started offering interactive features supporting training, mostly focused on athletic performance or serving accessibility purposes.

Image courtesy of WaveLight

Run! [28]
Run! is a High-tech running track along a popular public running route. Through an adaptive light system it stimulates a more intense training and inspires (more) people to exercise.

Slimme Beweegroute [9]
The Slimme Beweegroute ('Smart Exercise Route') is a 1.8 km walking and running path consisting of LED tiles in a public park.
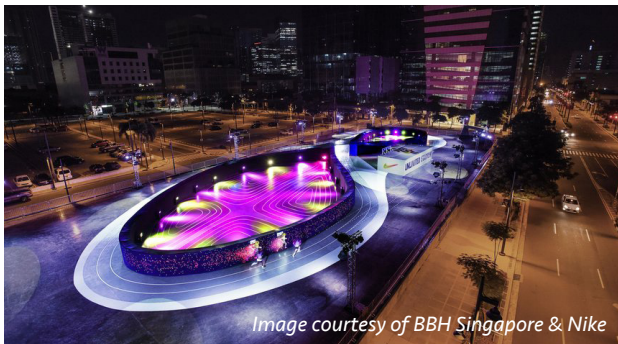
#WaveLight [35]
#WaveLight is an electronic pace-setter guiding runners on time, speed and interval. Easy to install on existing and new athletics tracks, it comprises of 400 LED lights placed in the drainage covers.

Temporary high-tech sport facilities

Temporary high-tech facilities target athletes and often act as marketing events for international sports brands. These innovative pop-up environments make impressive use of technology, combining multiple sensors, and providing a unique user experience mainly focused on performance.

Active Outdoor Office Infrastructure

Active office environments are designs located in the surroundings of office buildings, with the intention to trigger physically active ways of working.

Image courtesy of BBH Singapore & Nike

Image courtesy of AKQA & Nike

Nike Unlimited Stadium [2]
Nike Unlimited Stadium, described as the world most innovative training environment, tracks a runner's lap time using hyper-accurate Radio-frequency identification. The next lap, your avatar appears, running your previous time to beat. It thus challenges you to keep bettering your best

Nike Rise House of Mamba [1]
House of Mamba is a full-sized LED basketball court for the NIKE RISE basketball tour which took place across China. It utilizes motion-tracking and reactive LED visualization to train and challenge the players through authentic drills based on Kobe Bryant's training.

The Hubs [10]
Along a route for walking meetings, a network of Hubs supports work-related tasks such as presenting and notetaking. The Hubs facilitate this type of physically active meeting practice by gaining social acceptance within the organisational culture and overcoming obstacles related to walking meetings [11].

Interactive Public Installations

Interactive public installations are the most common type of interactive environments in the public space. Targeted at a wide audience, they often rely on principles of fun and gamification. Several of these projects (e.g., Piano Stairs [40], Musical Swings [7], Urbanimals [26]) are gaining public recognition through design awards. They are usually ephemeral and "on tour" in different cities. Reflecting on their transformative qualities, it appears that their user experience primarily relies on a novelty and stimulation factor, which might fade away across time.

Piano Stairs [40]
The iconic Piano Stairs project by the Fun Theory (2009) in Stockholm, Sweden nudges people into taking the stairs rather than the escalator.

Photo by KJ Vogelius

Stride [25]
Stride is a student project composed of a forest of poles, featuring interactive stepping stones. When pressure is detected on a stone, the step lights up and plays a sound.

Image courtesy of TU Delft
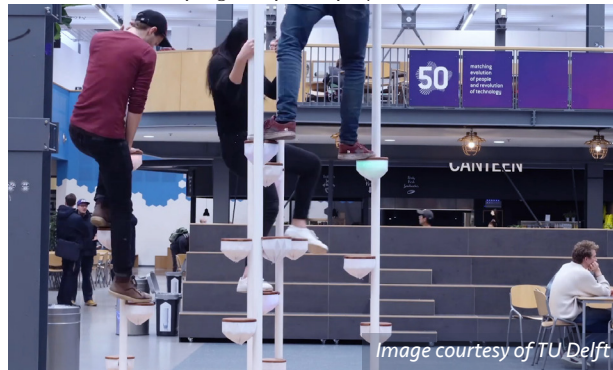
Urbanimals [26]
These interactive projected animals by LAX encourage to explore the city and play with them, invoking activeness and creativity.
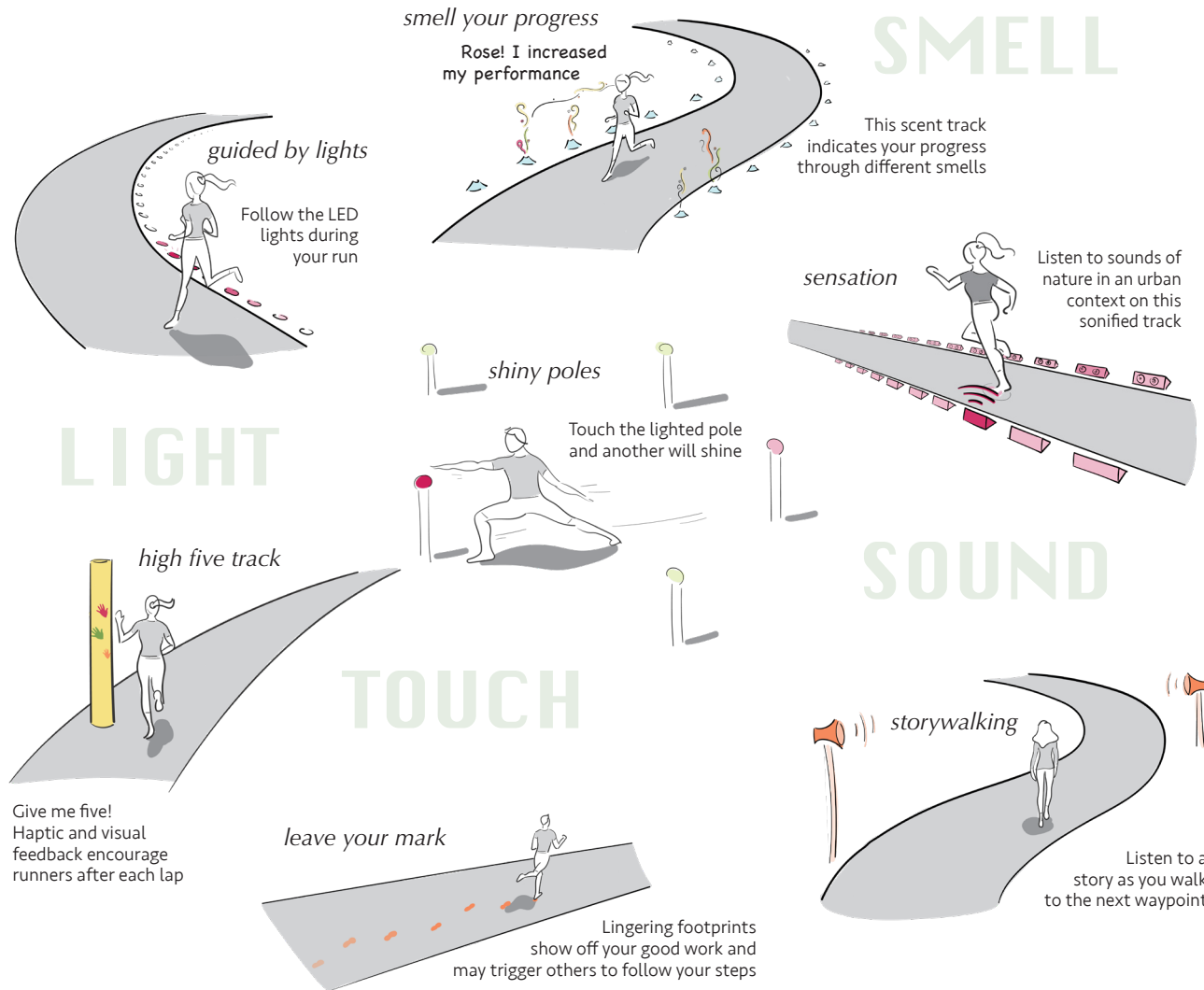

Photo by Paul Blakemore

Musical Swings [7] & the Pearl Divers [8]
Musical Swings and Pearl Divers are interactive installations, designed by Daily Tous les Jours, which invite passerby to make music together with their entire bodies. They represent an emergent field of practice combining technology, storytelling, performance and placemaking.

Image courtesy of Daily tous les jours

Photo by Hardik

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DESIGN EXPLORATIONS

The second part of our design space exploration focused on ideation and sketches of interActive environments, mostly related to walking and running in urban environments, based on literature and design research and explorations from Industrial Design students and researchers projects over the last two years. As this design activity was exploratory in nature, aimed at mapping out the design space of interActive environments, most of these concepts remained at the conceptualisation stage and a selection only was further developed into prototypes (see Design cases). Reflecting back, we used affinity diagramming to classify the sketches into themes (see also Figure B, p.12) and share the insights we gained from these explorations. Illustrative examples are depicted, some overlapping between several levels of analysis. Further reflections on domains not represented in the sketches are suggested.
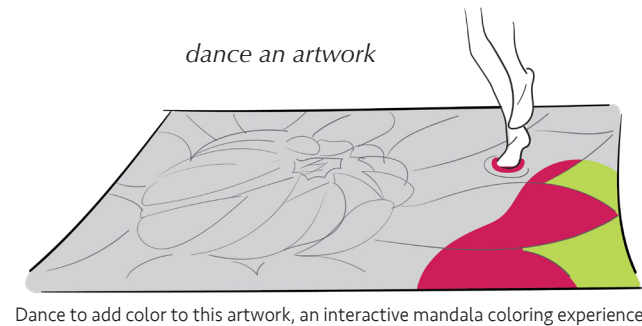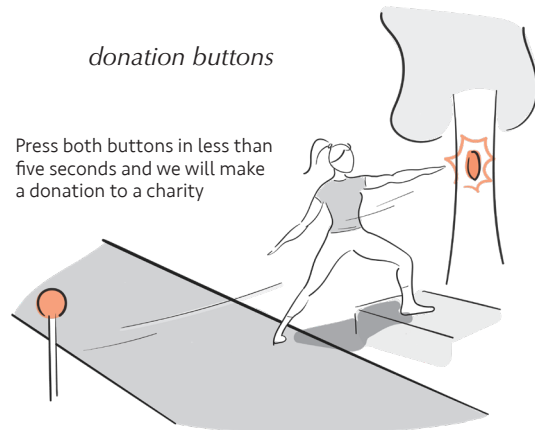
SMELL

smell your progress

Rose! I increased my performance

This scent track indicates your progress through different smells

guided by lights

Follow the LED lights during your run

sensation

Listen to sounds of nature in an urban context on this sonified track

LIGHT

shiny poles

Touch the lighted pole and another will shine

high five track

SOUND

Give me five! Haptic and visual feedback encourage runners after each lap

TOUCH

leave your mark

storywalking

Listen to a story as you walk to the next waypoint

Lingering footprints show off your good work and may trigger others to follow your steps
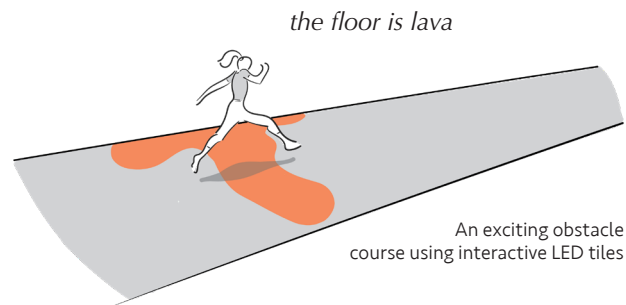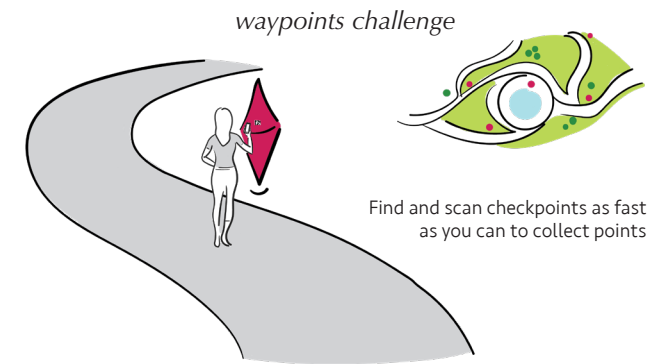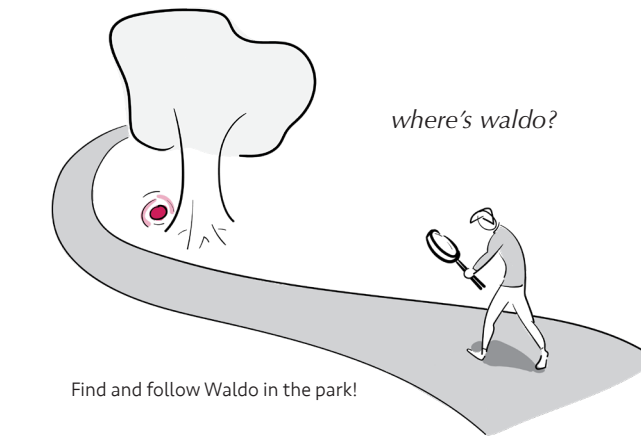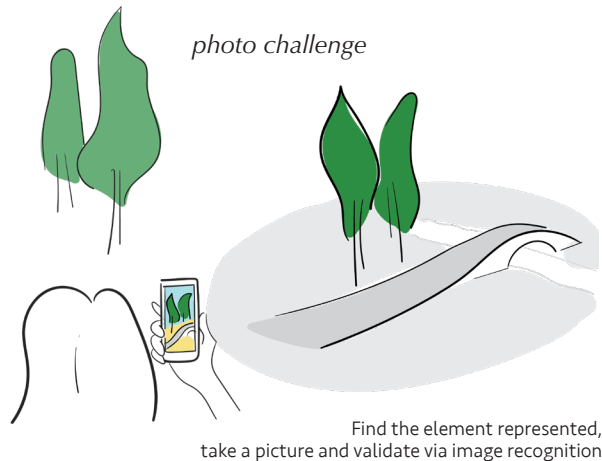
INTERACTION MODALITY

We first can distinguish several channels of sensory input/output between the environment and the user. The most common interaction modalities were the use of auditory and visual feedback. In line with its predominance in the benchmark, light (using LEDs) tends to be the first idea coming to the mind of designers. It is undeniably a relevant and less intrusive type of feedback in outdoor environments, as compared to sound or smell, but often less visible on a bright day. In our sketches, sound is explored in relation to storytelling, mindfulness and music, which is a common element in recreational running [18], as well as for motivation and guidance. In the storywalking concept for instance, you would listen to a story as you walk to the next waypoint. While being a popular modality used in running-related smartphone apps or in the practice of runners simply listening to their favorite playlist, sound seems rarely encountered in interActive environments. Of course, it is a somewhat disturbing modality in the public space, which could cause nuisances or privacy concerns. Yet there might be intriguing opportunities there too: sound attracts attention, creates a specific ambiance and might stimulate social exchanges and shared user experiences.

Haptic feedback is used to augment the experience or bring a fun element to it. Way less common is the use of smell, only present in a couple of sketches where the designers forced themselves to explore all human senses. The 'smell your progress' concept for instance suggests to use a variety of scents to represent success and performance. Olfactory feedback, while interesting, currently seems challenging to achieve in outdoor environments and might even compete with natural pleasant scents (e.g., freshly cut grass, rain, forest). Designers might get inspired by the use of scents in the field of marketing and retail, where numerous investigations have been made on how it impacts consumer experiences and nudges them into buying behaviors. Translated to the exercising area, one could attract walkers or runners to the next milestone by the use of smell, just like bakeries attract consumers with the irresistible smell of freshly baked bread or pastries. The last of our five senses, taste, was considered yet remained absent from the sketches collected. Rare examples of designs in the field of sports make use of this modality, as Tasty Beats [19] or Edipulse (turning physical activity into chocolates) [20]. Finally, designers of interActive environments can also make use of senses related to the vestibular system, such as gravity, movement and balance.

INTERVENTION STRATEGY

Designed environments make use of various intervention strategies, in order to create a positive experience or to trigger behavior change and nudge people into moving.

photo challenge

Find the element represented, take a picture and validate via image recognition

donation buttons

Press both buttons in less than five seconds and we will make a donation to a charity

where's waldo?

Find and follow Waldo in the park!

the floor is lava

An exciting obstacle course using interactive LED tiles

dance an artwork

Dance to add color to this artwork, an interactive mandala coloring experience

waypoints challenge

Find and scan checkpoints as fast as you can to collect points

Fun/Gamification

The most common explored strategy was the use of fun or gamified elements. Considering recreational sport as a leisure activity, these concepts highlight ways to use interactive technology to design playful experiences. Some concepts include challenges in order to stimulate exploration of the environment (e.g., waypoints challenge or photo challenge, where's Waldo?), while others link the activity to charitable causes (e.g. making a donation) potentially during pop-up sponsored events. Other concepts were directly inspired by popular games, such as 'the floor is lava' or 'where's Waldo?'. Finally some more stationary (as in, located at a single place in the urban park) forms of art installations can contribute to the attractiveness of the environment and stimulate people's creativity (e.g., dance an artwork). These are in line with the installations showcased in the benchmark section.
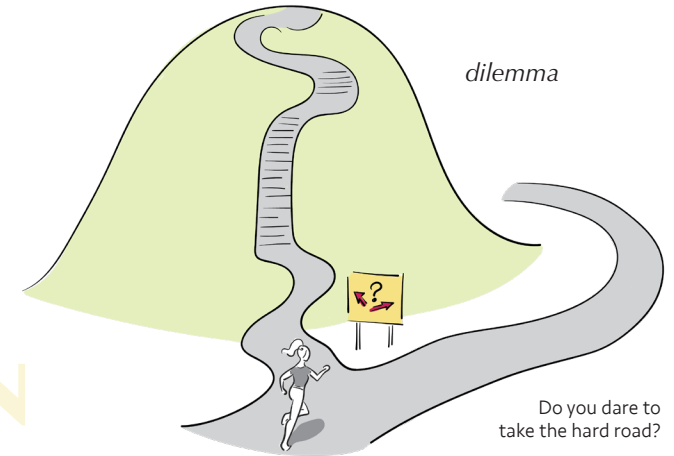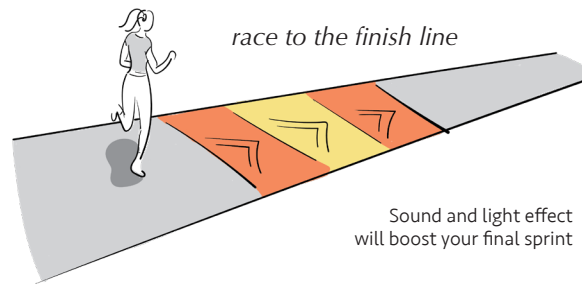
Various technological supports were envisioned to design these experiences: to log in, the use of RFID tags, QR codes or apps using geolocalization; to interact, the use of pressure sensors in LED panels or image recognition.

This strategy is particularly inclusive to various age ranges, as playful elements might appeal to a wide audience and also triggers social experiences. Existing gamified outdoor environments are usually targeting children, so there is an interest in designing interventions beyond this target group. One limitation however is that the novelty effect of some of these concepts might fade over time.
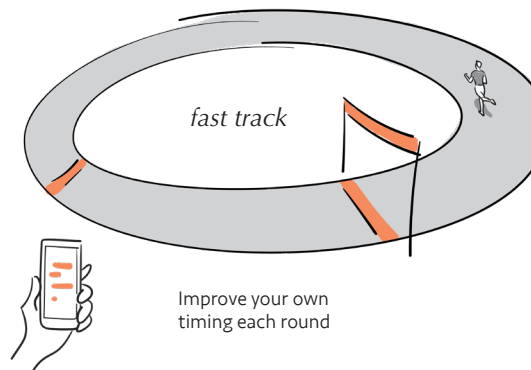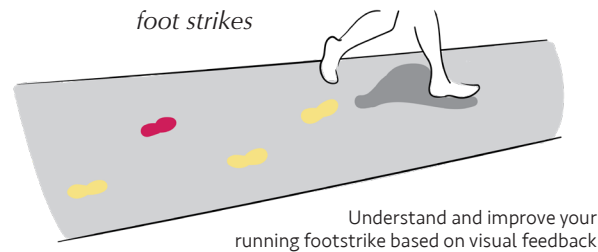
Performance / Competition

Besides leisure use, a number of sketches from our explorations used competitive or performance-related elements. These use mastery and the need for competence as a main trigger for engagement. On the technical side, the ideation focused on running training such as cadence, interval training or adequate foot strikes (e.g., musical cadence training, foot strikes or tempo indicator). Other concepts made use of competitive elements, attempting to make users train faster or harder (e.g., dilemma, race to the finish line, or fast track).
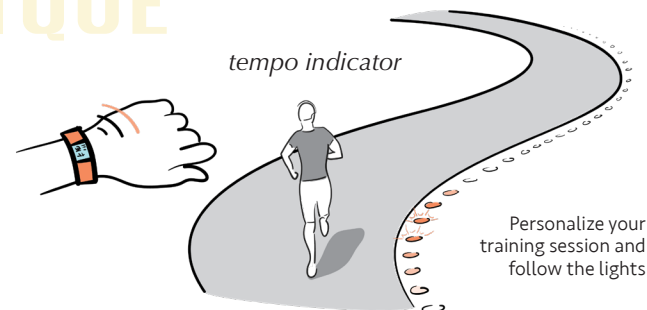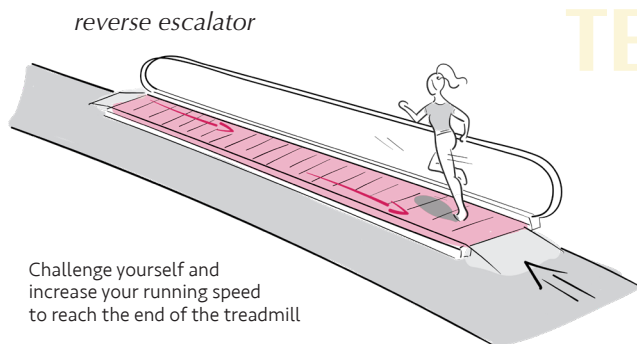
These concepts sometimes require additional inputs, such as data from smartwatches or exercising apps, especially when the users wish to set personal goals or keep track of their progress over time. Exploring these options led to discussions about the benefits of personalization of these experiences. More specifically, which forms of personalization could be suitable for the design of InterActive environments where the main focus stays on a public installation that is by essence shared, and not having access to personal data about its users.

race to the finish line

Sound and light effect will boost your final sprint

dilemma

Do you dare to take the hard road?

COMPETITION

fast track

Improve your own timing each round

foot strikes

Understand and improve your running footstrike based on visual feedback

musical cadence training

Stay in time with the beat to improve your running cadence

TECHNIQUE

reverse escalator

Challenge yourself and increase your running speed to reach the end of the treadmill

tempo indicator

Personalize your training session and follow the lights

Social Support

Despite a rather individualistic view on outdoor recreational physical activity, our explorations also include sketches linked to social support. This is mostly done through a virtual representation of a supportive crowd (the clapping track), or messages from fellow exercisers (message to strangers). Some concepts adopted a tailored approach to support, by customizing supporting messages to individuals (personal billboard).
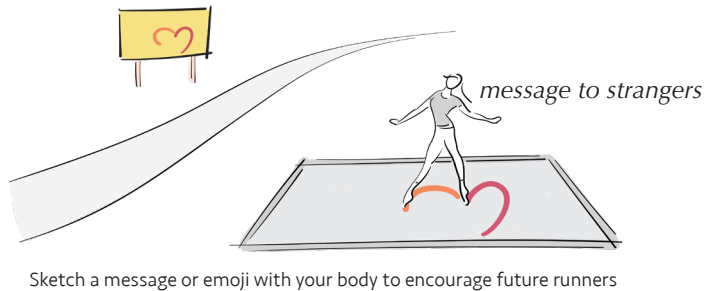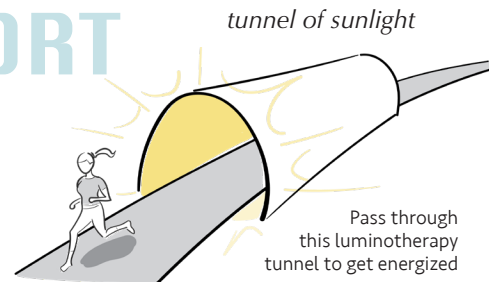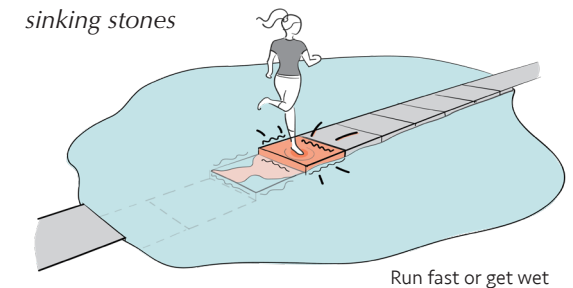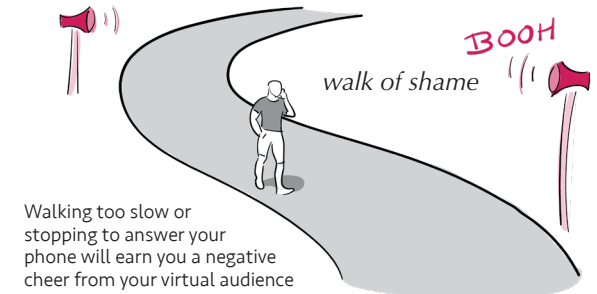
message to strangers

Sketch a message or emoji with your body to encourage future runners

personal billboard

Check-in and get personalized encouragement messages along your running route

here comes the sun

Visual prompts give you a taste of summer, anytime

SOCIAL SUPPORT

OVERCOMING OBSTACLES

warning walk

Warning labels depict bad health effects of an inacitve lifestyle

the clapping track

Great job! A virtual crowd is clapping for you

tunnel of sunlight

Pass through this luminotherapy tunnel to get energized

human dryer

Run even on rainy days

PROVOCATIVE

BOOH

walk of shame

Walking too slow or stopping to answer your phone will earn you a negative cheer from your virtual audience

sinking stones

Run fast or get wet

### Miscellaneous

Finally, some of the sketches were harder to categorize and presented out-of-the-box ideas meant at pushing the boundaries of the design space. These covered aspects of convenience meant to overcome the obstacles related to outdoor activity: what about a human-size dryer to invite outdoor running even on rainy days? or a luminotherapy tunnel to get energized even when there is no sunlight? Starting from the reward vs. punishment idea, some concepts adopted a more provocative design perspective, by shocking (warning walk), shaming (walk of shame) or troublemaking (sinking stones). The idea of sense deprivation (e.g., walk in the dark), in opposition to the use of the different human senses as a modality for design, also falls on the provocative side.
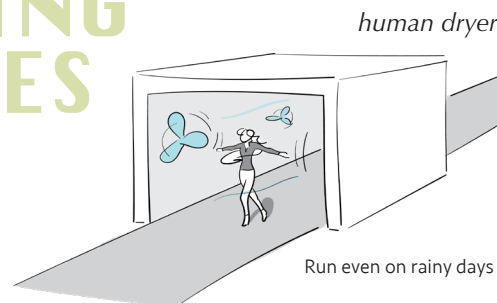
The broad and rather open insights gained during the concept explorations led us to identify several research questions and design opportunities. For instance, the use of sensorial modalities to "augment" the environment, the ability to personalize an experience without accessing personal data, or the use of modular gamified elements triggering discovery.

Following a Research-through-Design process [42][43], we prototyped three concepts - each representing a different design strategy - and deployed them during field tests. The design cases presented in this section are to be understood as design exemplar feeding our exploration of the design space. It is thus out of the scope of this pictorial to describe the user evaluation methodology and findings in details. We thus report on general impressions able to feed reflections around the interActive environment design space.

Guided by Lights: Personalized Feedback

Guided by Lights [31] is a LED path combined with a live speed indicator that supports runners or walkers to set personal goals and gain intrinsic motivation to be physically active. The design focuses on aspects that positively impact motivation and/or performance: personalization, goal setting, and feedback mechanisms. An initial evaluation of a prototype placed in three public parks, showed that participants (N=35) appreciated the personalization of the route and its goal-setting opportunities. They however found the visual light feedback hard to perceive during daytime. While embodying a form of personalization, the use of the system remained anonymous (the first part of the track measures one's speed and the light followed it subsequently), which offers advantages to onboard any user in the park without the need for an additional system.

DISCOV: Challenge and Exploration

Discov is a network of physical waypoints that triggers to explore its surroundings in a fun and challenging way by creating an engaging walking experience. Discovpoints attract passers-by with light feedback, who can then interact with it to get different kinds of light feedback. The Discovpoints do not form one route together, they simply show in which direction other Discovpoints can be found when users step off again. This encourages users to continue their playful and healthy discovery journey in the urban park at their own convenience. Through its engaging and explorative nature, Discov additionally increases mindfulness as it distracts people from their day-to-day worries by drawing their attention to their current surroundings.

First usertests (N=15) showed that an initial interaction helps to let people know it 'does something' but keeping it vague inspires first curiosity and then satisfaction. This both lengthens and enhances the interaction. Similarly, the direction indications were clear enough to demonstrate there are more points to find, but the distance and multiple point signals were not always understood. Again, this caused some confusion that mostly added to the desire to explore and find out. A good balance between obvious interactions and hidden aspects can trigger interest and exploration, and helps to engage users over a longer time.
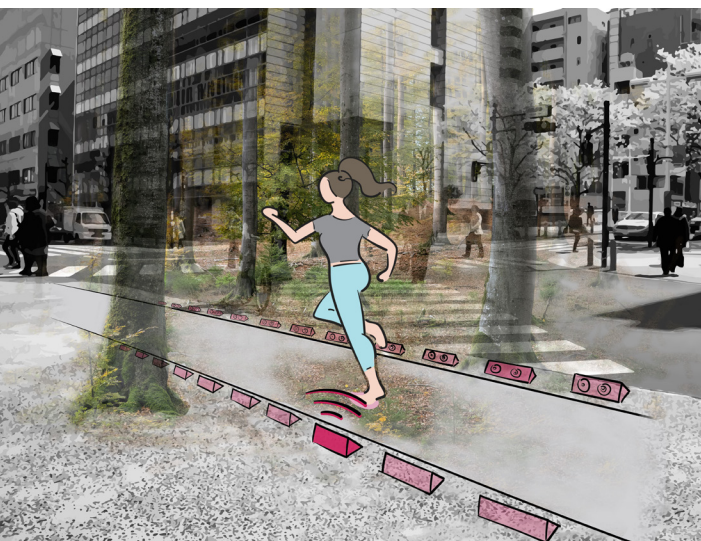
Sensation: Augmented Environment Through Sensorial Design

Sensation [32] is a sonified running track that that enriches the experience of running by providing sensations of nature through audio feedback. It detects footsteps on its surface and produces synced sounds of footsteps from a selected nature landscape (breaking branches, water puddles, leaves or snow) to augment the urban landscape. Building on the knowledge that adding natural sounds helps to improve the urban sonic environment [33] and more natural surroundings are preferred by runners [12] [24][27], Sensation uses natural sounds as audio feedback to improve the sonic landscape and support feelings of relaxation and mindfulness during a run. Embedded in the physical environment, Sensation is accessible to all passers-by, and therefore more inclusive than any concept requiring a prior investment or conscious action from the user. An initial usertest showed that locating the speakers close to the foot adds to the 'natural' feel, while wearing headphones were perceived as more artificial and inducing disconnection with the physical environment. Additionally, when embedded in the environment the positive effects of the added natural sounds benefit all close enough to hear. Further user explorations showed that the special experience offered by the artefact could attract people into the urban park. A side effect could also be to attract children and families in search of playful environments.

The Crowdsourced Marathon: Social Support

The crowdsourced marathon [6] is a futuristic marathon experience, focused on the relation between the crowd and the runners. After this exploration of cheering feedback, including a remote dimension, we reflected on how to translate the social aspects of the concept to an urban park environment. The popularity of social platforms amongst recreational runners (e.g. Strava [38], Runkeeper [15]) indicates a need for social support about one's achievements. Transferring the cheering wave to a more casual running context, and allowing one's friends to cheer for us during a running session, might trigger a meaningful social experience. In this exploration, the combination between physical elements in the environments and a smartphone application was of special interest and provided rich opportunities for interaction.

REFLECTIONS

In this exploration we analyzed benchmarked projects, exploratory sketches and design cases, with a specific focus on interaction modalities, intervention strategies and the technological opportunities and challenges. The present work proposes an initial classification of the design space of interActive environments. It does not claim to present a comprehensive list of all possible interactions, intervention levels or technologies, but the examined examples highlight a number of interesting insights meant to inspire researchers and designers. Through our benchmark and experts interviews, we noted that examples of truly interactive urban environments are somewhat scarce. Urban spaces and especially public parks offer a lot of low tech equipment (e.g. calisthenics equipment, cycle lanes) with installations often focused on children (e.g., playground design). This is in line with studies reviewing characteristics of urban parks associated with park use and physical activity [27] [30]. High-tech interactive sport installations [1][2] appear as ephemeral initiatives, initiated by sports brands for branding purposes. They impress by their innovativeness, yet seem hard to fund and maintain by public authorities. Similarly, artsy public installations triggering movement [8][7] attract a lot of attention from the public and the media thanks to their high creativity level, yet they also fail to sustain and scale up. An interesting question is: How can we translate the poetry and engagement created by these installations to a sustained use in public parks?

From the classification matrix of our exploratory sketches (Figure B) and design use cases, we see opportunities to explore the richness of interaction modalities beyond the common visual light feedback. Even using LED technologies, creative freedom remains vast. Other affordable sensors offer new design opportunities: RFID tags, bluetooth beacons, pressure sensors and more. Many of the concepts we explored involved a network of modular elements wirelessly connected to each other, locally or via the cloud. This enables more integrated, hollistic solutions for a harmonized experience, unconstrained by the scale of the urban public space.

The increasing amounts of both user-generated and environmental data at our disposal provide new insights into personal behavior and preference. Combined with technology, this data can also be used to tailor users' experiences, even in the urban space. Despite the variety and availability of sensors, in this exploration of the design space of interActive environments we see a limited use of the data they provide. Mainly used to trigger a direct response, usually in the form of pre-set visual or auditory feedback, user data is not further processed or utilized. Following the recent
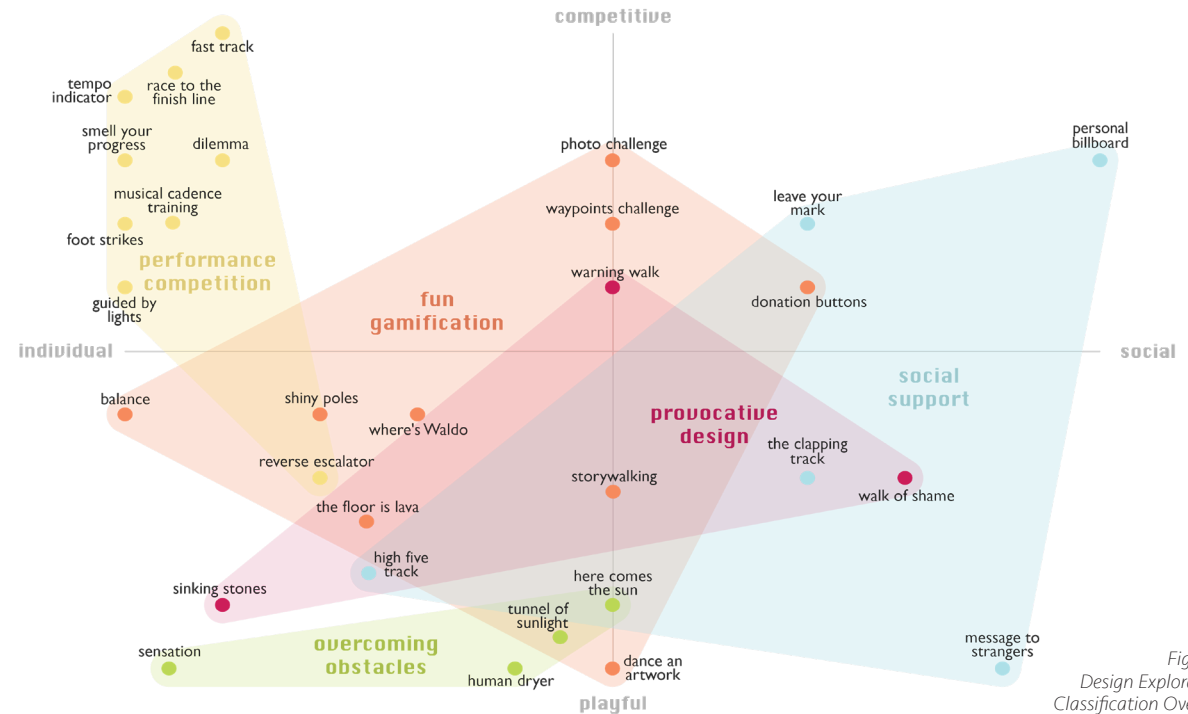

Figure B: Design Explorations Classification Overview

'Data-enabled design' approach by van Kollenburg en Bogers [5], data could be used as a creative material to gain user insights trigger innovative ideas within design processes. Additionally, the opportunities this type of data use provides regarding remote alterations, updates or problem solving of the system are specifically suited for installations placed in the public outdoor space. While privacy is obviously a key concern and endeavor, especially in the public space context, user-generated data could support the design of tailored interventions which are important in the domain of behavior change.

With their technology embedded in the physical environment, interActive environments have the potential to reach everyone in their vicinity, without any prior investment required from the user to benefit from the experience. This makes these interventions much more inclusive than many other available technologies to increase physical activity, even for the hard-to-reach group of people who are not consciously trying to change their inactive routines. Based on the limited number of more permanent installations we encountered, keeping users engaged in the long run might however prove more challenging. Future reflections could revolve around using the potential of technology to

personalize these interactions [37] and the need for adjusted and more interdisciplinary approaches that will be needed to design these truly interActive environments.

CONCLUSION

In this pictorial, we explored the design space of interActive urban environments through a benchmark, sketches, and designed artefacts. This analysis, inspired by the authors' own experiences researching and designing interActive environments is a relevant and timely contribution to consider how technology can help understand and shape human behavior in urban space. We envision the present design space to create a base for discussing challenges and issues related to this topic and to provide inspiration for designers and practitioners.

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